SECTION 4: RF, MICROWAVE, MAGNETIC FIELD AND OTHER NON-IONIZING RADIATION

4.1 INTRODUCTION

Static magnetic fields, microwave, and other radio-frequency radiations are produced by a wide variety of industrial, scientific, home appliance, and communication equipment. At sufficiently high intensities, exposure to static, RF, and microwave electromagnetic fields can produce a variety of adverse health effects. Such effects include cataracts of the eye, overloading of the thermoregulatory response, thermal injury, altered behavioral patterns, convulsions, and decreased endurance. It is the purpose of this section to provide safety guidelines to minimize the potential hazards to health that radio frequency, microwave, and static-magnetic field generating equipment present to PPPL employees and visitors. This section does NOT apply to laser radiation. See ESHD 5008, Section 3, "Laser Safety" for this hazard.

4.2 SCOPE AND PURPOSE

The intent of this section is to prevent harmful effects in human beings exposed to static and sub-radiofrequency magnetic fields and electric fields; radiofrequency and microwave radiation; and visible, near-infrared and ultraviolet radiation. These recommendations are not intended to apply to the purposeful exposure of patients by or under the direction of practitioners of the healing arts in which, of course, PPPL does not engage.

4.3 DEFINITIONS AND GLOSSARY OF TERMS

Exposure - Exposure occurs whenever and wherever a person is subjected to electric, magnetic, or electromagnetic fields or to contact currents other than those originating from physiological processes in the body and other natural phenomena.

Exposure, partial-body - Exposure that results when RF fields are substantially non-uniform over the body. Fields that are non-uniform over volumes comparable to the human body may occur due to highly directional sources, standing-waves, re-radiating sources, or in the near field region of a radiating structure.
See *RF "hot spot."*

Exposure Limit *– A value to which it is believed that nearly all workers may be exposed without adverse health effects. The values are based on the best available information from experimental studies and should be used only as guides in the control of exposures to the various forms of non-ionizing radiation covered in this section and should not be regarded as fine lines between safe and dangerous levels. These values apply to exposure during an 8-hour workday.*

Far-Field Region - That region of the field of an antenna where the angular field distribution is essentially independent of the distance from the antenna. In this region (also called the free-space region), the field has a predominantly plane-wave character, i.e., locally uniform distributions of electric-field strength and magnetic field strength in planes transverse to the direction of propagation.

Gauss (G) -. The CGS-electromagnetic unit of magnetic flux density. One Gauss (G) = 10^{-4} tesla = 0.1 millitesla (mT).

Hertz (Hz) - The unit for expressing frequency, f. One hertz equals one cycle per second.

Magnetic Field Strength (H) - A field vector that is equal to the magnetic flux density divided by the permeability of the medium. Magnetic field strength is expressed in units of amperes per meter (A/m).

Magnetic Flux Density (B) - A field vector quantity that results in a force (F) that acts on a moving charge or charges. The vector product of the velocity (v) at which an infinitesimal unit test charge, q, is moving with B, and is the force that acts on the test charge divided by q.

$$\frac{\boldsymbol{F}}{q} = (\boldsymbol{v} \times \boldsymbol{B})$$

Magnetic flux density is expressed in units of tesla (T). One T is equal to 10^4 gauss (G).

Mixed Frequency Fields - The superposition of two or more electromagnetic fields of differing frequency.

Near-Field Region - A region generally in proximity to an antenna or other radiating structure, in which the electric and magnetic fields do not have a substantially plane-wave character, but vary considerably from point to point. The near-field region is further subdivided into the reactive near-field region, which is closest to the radiating structure and contains most or nearly all of the stored energy, and the radiating near-field region where the radiation field predominates over the reactive field, but lacks substantial plane-wave character and is complicated in structure.

NOTE: For most antennas, the outer boundary of the reactive near-field region is commonly taken to exist at a distance of one-half wavelength from the antenna surface.

Power Density (*S*) - Power per unit area normal to the direction of propagation, usually expressed in units of watts per square meter (W/m^2), or for convenience, in units such as milliwatts per square centimeter (mW/cm^2) or microwatts per square centimeter ($\mu W/cm^2$). For plane waves, power density, electric-field strength (E) and magnetic-field strength (H) are related by the impedance of free space, i.e., 377 ohms. In particular,

$$S = \frac{E^2}{377} = 377H^2$$

where E and H are expressed in units of V/m and A/m, respectively, and S in units of W/m^2. Although many survey instruments indicate power density units, the actual quantities measured are E or E^2, or H or H^2.

Power Density, Peak - The maximum instantaneous power density occurring when power is transmitted.

Radio Frequency (RF) – Non-ionizing, electromagnetic energy characterized by relatively long wavelength, low frequency, and low photon energy. Although the RF spectrum is formally defined in terms of frequency as extending from 0 to 3000 GHz, for purposes of this section, the frequency range of interest is 3 kHz to 300 GHz with microwave range from 300 MHz to 300 GHz.

Region	Frequency	Wavelength	Photon Energy
Microwave	300 GHz – 300 MHz	1 mm – 1 m	1.24 meV – 1.24 μeV
Radio wave	300 MHz – 3 kHz	1 m – 100 km	1.24 μeV – 0.01 neV

Note: RF is considered non-ionizing radiation because the photon energies are well below the 10 to 12 eV necessary to ionize water molecules.

Re-radiated Field - An electromagnetic field resulting from currents induced in a secondary, predominately conducting, object by electromagnetic waves incident on that object from one or more primary radiating structures or antennas. Re-radiated fields are sometimes called "reflected," or more correctly, "scattered fields." The scattering object is sometimes called a "re-radiator" or "secondary radiator" (see *scattered radiation*).

RF "Hot Spot" - A highly localized area of relatively more intense radio-frequency radiation that manifests itself in two principal ways:

1. The presence of intense electric or magnetic fields immediately adjacent to conductive objects that are immersed in lower-intensity ambient fields (often referred to as re-radiation).

2. Localized areas, not necessarily immediately close to conductive objects, where there exists a concentration of radio-frequency fields caused by reflections and/or narrow beams produced by high-gain radiating antennas or other highly directional sources.

In both cases, the fields are characterized by very rapid changes in field strength with distance. RF hot spots are normally associated with very non-uniform exposure of the body (partial-body exposure). This is *not* to be confused with an actual thermal hot spot within the absorbing body.

Root-Mean Squared (rms) - The effective value, or the value associated with joule heating, of a periodic electromagnetic wave. The rms value is obtained by taking the square root of the mean of the squared value of a function.

Scattered Radiation - An electromagnetic field resulting from currents induced in a secondary, conducting, or dielectric object by electromagnetic waves incident on that object from one or more primary sources.

Short-term Exposure - Exposure for durations less than the corresponding averaging time.

Wavelength (λ) - In a monochromatic wave, the distance between two points of corresponding phase of two consecutive cycles in the direction of propagation. The wavelength (λ) of an electromagnetic wave is related to the frequency (f) and velocity (v) by the expression $v=f\lambda$. In free space the velocity of an electromagnetic wave is equal to the speed of light, i.e., approximately $3x10^8$ m/s.

4.4 RESPONSIBILITIES

4.4.1 Department/Project/Division Heads are responsible for ensuring that all employees under their direction follow the requirements and procedures in this section.

4.4.2 Supervisors are responsible for the enforcement of the requirements and procedures of this section including:

A. Ensuring that safe operating procedures pertaining to magnetic fields and RF and microwave operations are established and executed.

B. Providing adequate instructions in safety practices for all personnel who work with or near RF and microwave equipment where any potential exposure could exceed the exposure guidelines (Tables 2 and 3).

C. Making arrangements with the RF Engineering Group to perform surveys immediately following modifications, and at regular intervals (at least annually) of RF and microwave sources, as noted in Paragraph 4.6.4.

D. Making arrangements with Industrial Hygiene to perform magnetic field surveys. Alternatively, these surveys may be conducted by any individual using calibrated equipment, provided that the person has documented training on the use of the survey equipment.

E. Ensuring that documented tests are performed on all safety devices (interlocks, signals) when installed and at least annually thereafter.

F. Consulting with Industrial Hygiene and the RF Engineering Group before RF or microwave equipment is installed or extensively modified. Maintenance or repair of established equipment is excepted.

G. Consulting with Health Physics if any RF or microwave generating power source is capable of producing X-rays prior to operation and after extensive modifications for monitoring and appropriate control measures.

H. Providing copies of all conducted surveys and operating procedures to Industrial Hygiene.

4.4.3 Users are responsible for complying with the provisions of this section and for notifying the Occupational Medicine Office of any implanted medical devices that may be affected by non-ionizing radiation such as cardiac pacemakers, cardiac defibrillators, prostheses, insulin pumps, suture staples, aneurysm clips, etc.

4.4.4 The Occupational Medicine Office is responsible for:

A. Notifying the employee, the immediate supervisor, and Industrial Hygiene when any deviation from normal health is observed that may be work-related.

B. Working with Industrial Hygiene to resolve potential issues regarding non-ionizing radiation exposure to individuals with implanted medical devices

4.4.5 Industrial Hygiene (IH) is responsible for assisting in the implementation of this section. Specifically:

A. IH shall assist in establishing safety guidelines pertaining to non-ionizing radiation-producing equipment.

B. IH shall review and appraise safety procedures for the use of non-ionizing radiation-producing equipment.

C. IH shall assist in providing adequate instruction in safety procedures to users who work with or may be exposed to non-ionizing radiation.

D. IH shall maintain copies of all RF leakage survey data for at least one year.

4.4.6 The RF Engineering Group is responsible for:

A. Developing and maintaining an RF Surveyor Training Standard to ensure proper training for personnel performing RF leakage surveys. This training shall include at a minimum:

1. Definitions and hazards pertaining to RF radiation

2. Locations of possible RF emanations for sources to be surveyed

3. Proper use of RF monitoring equipment

4. Proper controls for safe access to RF generating equipment.

B. Training RF Surveyors to perform RF leakage surveys.

C. Performing leakage surveys of all RF equipment at least annually and after extensive modifications to systems. This activity may be delegated to other Trained RF Surveyors outside the Group as appropriate.

D. Providing copies of all RF leakage survey results to Industrial Hygiene.

E. Training and/or Qualifying, as necessary, RF Technicians to safely perform work on RF equipment, and providing a record of that training to Human Resources. This training will at a minimum include all items in paragraph 4.4.6.A above.

4.5 REQUIREMENTS

4.5.1 Protection against the following must be provided:

A. Thermal - Since radiation in the frequency range of 10 MHz to 300 GHz is not energetic enough to produce ionization in living organisms, it is generally accepted that the principal effect of absorption of this energy is a rise in internal temperature.

B. Ancillary hazards, which arise from the generating equipment used to produce radiant energy at significant levels, include:

1. High voltage on components that are on or near the radiating elements.
2. Electric arcing to conducting surfaces from radiating elements at close range.
3. High-power, RF-induction heating units inducing high current in metal objects placed near the radiating element. Although the radiation itself may be harmless, the unexpected intense heat in the object could cause severe burns.
4. Burns to the skin by direct contact with RF potentials.
5. Radiation from RF and microwave equipment inducing energy in another apparatus that can interfere with operation of associated circuits including control circuits, bio-electronic implants (such as pacemakers), and ionizing radiation survey instruments.

C. Electrical Hazards - In addition to the hazards identified above, electrical hazards include or are a consequence of:

1. Inadequate shock-reaction space;
2. Induced voltages in closed magnetic circuits;
3. High impedances in grounding conductors;
4. Improper lockout/tag-out practices;

4.5.2 Non-Ionizing Radiation Producing Equipment Electrical Safety

The requirements of this subsection are supplementary to ES&H Manual, Section 2.0, "Electrical Safety." Examples of electrical safety equipment include:

A. Fail-safe Control Systems

B. Barriers and Safety Interlocks

C. Safety Interlocks for Transmission Lines

D. Remote-control Interlocks

E. Warning Systems and Annunciators

F. Grounding Methods

G. Temporary By-passing of Safety Interlocks

H. Personnel Protective Equipment (PPE)

4.5.3 Design and Construction Practices

Ancillary apparatus for non-ionizing radiation producing equipment shall be designed and constructed in accordance with the following safety requirements:

A. A fail-safe control system shall be included, which maintains the desired protective function when a single mechanical or electrical component fails, or upon the failure of its power system, causing the system to go into, or remain in, a safe mode.

B. Fail-safe control systems shall be successfully analyzed before completion of the design.

C. Energy barriers, where required and readily removable (no tools required), shall have their positions monitored by initial control devices, such as limit, photocell, or proximity switches, and shall be considered part of the personnel safety interlock system for the RF/microwave equipment.

D. Equipment and service access-door positions shall be monitored where required by initial control devices having hard-wired final control elements arranged to de-energize the power supply for the RF/microwave equipment upon unauthorized access attempts.

E. Remote control of RF/microwave operation shall be delegated by sequentially-keyed locally-remote control stations. The sequential keying shall be considered part of the personnel-safety interlock (PSI) system for the RF/microwave equipment.

F. Visual indicators and annunciators used in RF activation warning systems shall have self-checking features, such as push-to-test lights, included in the system design.

G. Where single-point grounding systems are used with RF/microwave power supplies, systems, or structures, their design criteria shall be documented and approved by Electrical Safety of the ES&H Division. Covered copper braid or flat copper bar shall be considered for use as grounding conductors in circuits having fast rise-times.

4.5.4 Operating Criteria

Ancillary apparatus for RF/microwave equipment shall be operated in accordance with the following safety requirements.

A. A fail-safe control system shall be included, which maintains the desired protective function when a single mechanical or electrical component fails, or upon the failure of its power system, causing the system to go into, or remain in, a safe mode.

B. RF/microwave equipment safety training shall include capacitor bank accessor certification, where applicable, and orientation to the safety tagging procedures of PPPL Procedure ESH-016.

C. Periodic safety inspections shall be performed on personnel safety interlock systems and capacitor banks within operational RF/microwave systems as required by PPPL procedures.

4.6 Exposure Limits

Exposure to Non-Ionizing Radiation shall comply with guidelines issued in the American Conference of Governmental Industrial Hygienists (ACGIH) 2005 Threshold Limit Values for Chemical Substances and Physical Agents & Biological Exposure Indices. Excerpts of that document are included here.

4.6.1 Static Magnetic Fields

Routine occupational exposures should not exceed 60 millitesla (mT), equivalent to 600 gauss (G), whole body or 600 mT to the limbs on a daily, time-weighted average basis. Ceiling values are 2 T for the whole body and 5 T for the limbs. Safety hazards may exist from the mechanical forces exerted by the magnetic field upon ferromagnetic tools and medical implants. Cardiac pacemaker and similar medical electronic device wearers

should not be exposed to field levels exceeding 0.5 mT (5 G). Adverse effects may also be produced at higher flux densities resulting from forces upon other implanted devices such as suture staples, aneurysm clips, prostheses, etc.

4.6.2 Sub-Radiofrequency (30 kHz and below) Magnetic Fields

Occupational exposures in the extremely-low-frequency (ELF) range from 1Hz to 300 Hz should not exceed the ceiling value given by the equation: $B_{TLV}=60/f$ where f is the frequency in Hz and B_{TLV} is the magnetic flux density in millitesla (mT). For frequencies in the range of 300 Hz to 30 kHz, occupational exposures should not exceed the ceiling value of 0.2 mT. These ceiling values for frequencies of 300 Hz to 30 kHz are intended for both partial-body and whole-body exposures. For frequencies below 300 Hz, the exposure limit can be increased by a factor of 10 for the hands and feet and by a factor of 5 for the arms and legs. Contact currents from touching ungrounded objects that have acquired an induced electrical charge in a strong sub-RF magnetic field should not exceed the following point contact levels to avoid startle responses or severe electrical shocks: 1.0 milliampere (mA) at frequencies from 1 Hz to 2.5 kHz; and 0.4f mA at frequencies from 2.5 to 30 kHz, where f is the frequency expressed in kHz.

Some models of cardiac pacemakers and similar medical electronic devices have been shown to be susceptible to interference by power-frequency (50/60 Hz) magnetic flux densities as low as 0.1 mT. Lacking specific information on electromagnetic interference from the manufacturer, the exposure of persons wearing these devices should not exceed 0.1 mT at these frequencies.

4.6.3 Sub-Radiofrequency (30 kHz and below) and Static Electric Fields

Occupational exposures should not exceed a field strength of 25 kilovolts per meter (kV/m) from 0 Hz (direct current (DC)) to 100 Hz. For frequencies in the range of 100 Hz to 4 kHz, the ceiling value is given by $E_{TLV}=2.5 \times 10^6/f$ where f= the frequency in Hz and E_{TLV} = the electric field strength in volts per meter (V/m). A value of 625 V/m is the ceiling value for frequencies from 4 to 30 kHz. These ceiling values are intended for both partial-body and whole-body exposures. Contact currents from touching ungrounded objects are as listed above in paragraph 4.6.2.

4.6.4 Radiofrequency and Microwave Radiation

These exposure limits refer to radiofrequency (RF) and microwave radiation in the frequency range of 30 kilohertz (kHz) to 300 gigahertz (gHz). The exposure limits, in terms of root-mean-square (rms) electric (E) and magnetic (H) field strengths, the equivalent plane-wave free-space power densities (S), and induced currents (I) in the body which can be associated with exposure to such fields, are given in Table 1 as a function of frequency, f, in megahertz (MHz).

Table 1: Radiofrequency and Microwave Exposure Limits

Part A – Electromagnetic Fields (f=frequency in MHz)				
Frequency	Power Density, S (mW/cm^2)	Electric Field Strength, E (V/m)	Magnetic Field Strength, H (A/m)	Averaging Time E^2, H^2 or S (minutes)
30 kHz-100 kHz		614	163	6
100 kHz-3MHz		614	16.3/f	6
3 MHz-30 MHz		1842/f	16.3/f	6
30 MHz-100 MHz		61.4	16.3/f	6
100 MHz-300 MHz	1	61.4	0.163	6

300 MHz-3 GHz	f/300			6
3 GHz-15 GHz	10			6
15 GHz-300 GHz	10			616,000/f1.2

Note: The exposure values in terms of electric and magnetic field strengths are obtained by spatially averaging over an area equivalent to the vertical cross-section of the human body.

Part B – Induced and Contact Radiofrequency Currents, Maximum Current (mA)				
Frequency	Through Both Feet	Through Either Foot	Contact	Averaging Time
30 kHz-100 kHz	2000 f	1000 f	1000 f	1 second
100 kHz-100 MHz	200	100	100	6 minutes

Note: Access should be restricted to limit the RMS RF body current and potential for RF electrostimulation ("shock," below 0.1 MHz) or perceptible heating (at or above 0.1 MHZ).

Note: Microwave ovens operate at 2450 MHz and have an allowable leakage limit of 1 mW/cm2 for new units and 5 mW/cm2 thereafter.

Refer to the ACGIH 2005 TLV booklet (reference 4.9.4) for additional details.

4.6.5 Light and Near-Infrared Radiation

Exposure limits for visible and near-infrared radiation in the wavelength region of 385 nm to 3000 nm can be found in the ACGIH 2005 TLV booklet (reference 4.9.4).

4.6.6 Ultraviolet Radiation

Exposure limits for ultraviolet (UV) radiation with wavelengths in air between 180 and 400 nm can be found in the ACGIH 2005 TLV booklet (reference 4.9.4).

4.7 PRACTICES AND PROCEDURES

Equipment emitting RF and microwave radiations shall be operated in a manner such that exposure to operators and other personnel is minimized. In no case shall exposure exceed the limits stated in Paragraph 4.6. Three factors -- time, distance, and shielding -- can be utilized to minimize radiation hazards. RF and microwave radiation shall be subject to the following controls:

4.7.1 Administrative Controls

A. Access to RF/microwave areas shall be limited to qualified personnel. Signs and other visible and/or audible signals shall be used. The ANSI warning symbol (Appendix I) for non-ionizing radiation shall be included on all postings used to identify radiation areas. -Industrial Hygiene and the RF Engineering Group shall check for proper posting of signs.

B. Areas shall be posted according to the following guidelines:

1. Caution signs shall be posted in areas where the RF emissions approach the exposure limits on a regular basis.

2. Danger signs shall be posted in areas that have the potential to exceed the exposure limits unless precautions are taken.

C. Devices with directional beams of radiation shall be positioned so that energy is harmlessly absorbed and not directed into any occupied area.

D. Personnel shall not be permitted to make close visual examinations of energized microwave radiators and reflectors.

E. Personnel are not permitted to enter areas exceeding exposure limits without proper training from the RF Engineering Group and the approval of Industrial Hygiene.

4.7.2 Design and Construction Criteria for Original Equipment

A. Shielding and other control measures shall be provided to minimize radiation leakage.

B. Exposed dummy loads shall be appropriately guarded to prevent burns.

C. Adequately sized electrical-ground connections shall be provided.

D. Sharp edges or points on equipment should be eliminated to avoid corona discharge.

E. RF and microwave-heating equipment shall be designed with adequate clearances around RF leads.

F. Where possible, bypass capacitors should be provided on control power and instrument leads that enter the RF compartment to control leakage without interfering with proper operation.

G. Viewing ports, air inlets and outlets, etc., shall be designed and/or shielded to limit leakage radiation to acceptable levels.

H. Consideration shall be given to potential X-ray production in RF-generating equipment. Shields or barriers shall be designed into applicable system to minimize personnel exposure to these ionizing radiations. If ionizing radiation generation is possible for a system, contact Health Physics for monitoring and proper control methods.

4.7.3 Engineering Controls

A. Barriers and interlocks shall be used to prevent operators and maintenance personnel from accidentally entering areas where radiation and ancillary hazards exist.

B. Whenever tests are performed, radiating elements shall be replaced with dummy loads, where appropriate.

C. Whenever the potential for excessive radiation in occupied locations exists, area monitoring equipment should be considered as a fixed part of the installation.

D. When possible, the energizing switch for the equipment should be controlled by a preset elapsed-time mechanism to limit the exposure period automatically.

4.7.4 Surveys

A. RF surveys are required on all new installations and when modifications are made that affect wave guides, RF generation, coax lines, or other forms of RF transmission, and at least annually on all other RF emitting equipment. If equipment is not in use on the regularly scheduled survey date, the equipment shall be surveyed during the next start-up.

B. The survey shall be conducted by a Qualified RF technician (paragraph 4.4.6). A copy of the survey shall be sent to Industrial Hygiene.

C. Survey documentation should include as a minimum:

1. A sketch that indicates the RF source and survey measurement locations.

2. Whether the measurement is in the near or far field.

3. The instrument used, its type, model, serial number, and most recent calibration date. The most recent calibration shall be no older than one year or within manufacturer's recommended calibration period.
4. Survey data and any recommendations.
5. An indication of whether the RF energy leakage meets or exceeds the exposure limits for the specific non-ionizing radiation.

D. RF and microwave-survey meters shall be calibrated at least annually.

E. Microwave ovens must be kept in a clean and sanitary manner. Damage to the door seals of the microwave, or to the microwave itself, must be reported to Industrial Hygiene. IH will perform a RF leakage survey of any microwave suspected of damage.

F. Where the potential for X-radiation generation exists, the Health Physics Branch shall be requested to survey the installation and make any appropriate shielding or operational limitation recommendations.

G. Magnetic field surveys shall be conducted with a calibrated meter and copies of the results shall be sent to IH.

4.8 Medical Implant Safety

4.8.1 Heart pacemakers and similar medical electronic devices have been shown to respond to electromagnetic fields including RF and microwave in ways that could have an adverse affect on the device wearers. In order to protect personnel who wear medical electronic devices, access to the following areas is prohibited:

A. Where static magnetic fields may exceed 5 gauss (0.5 mT).
B. Where sub-radiofrequency (30 kHz and below) magnetic fields may exceed 1 gauss (0.1 mT).
C. Where static and sub-radiofrequency (30 kHz and below) electric fields may exceed 1 kV/m.
D. Within 5 feet of operating arc welding devices.
E. Vicinity of open-flux magnets and other devices, as posted.

*Access to generally restricted areas by medical electronic device wearers will be considered on a case-by-case basis if monitoring data is available and after consulting with the Supervisor, the Occupational Medicine Office, and with IH review and approval. Specific information on electromagnetic interference from the manufacturer of the pacemaker or similar medical electronic devices may be used to justify permission for access.

4.8.2 Areas where restrictions apply shall be posted by IH as "Pacemaker Wearer Keep Out" or similar.

4.8.3 Subcontractors, visitors, and members of tour groups who wear medical electronic devices will also be prohibited from entering these areas.

4.8.4 There is no prohibition against medical electronic device wearers being near microwave ovens. Modern devices are sufficiently well designed and microwave ovens sufficiently free of RF leakage that problems are not expected to arise.

4.8.5 Wearers of medical electronic devices and other medical implants should make themselves known to supervisors and to the Occupational Medicine Office. Supervisors are asked to cooperate by providing work-area reassignments for these individuals, if necessary.

4.8.6 Supervisors or employees who have questions about electromagnetic-field effects on medical electronic devices or other medical implants should contact Industrial Hygiene or the Occupational Medicine Office.

4.9 REFERENCES

4.9.1 CFR 21, Food and Drugs, Subchapter J, Part 1030, "Performance Standards for Microwave and Radio Frequency Emitting Products."

4.9.2 CFR 29, Labor Chap.1, Part 1910, Occupational Safety and Health Standards (OSHA) Subpart G, "Occupational Health & Environmental Control"; Part 1910.97, "Non-ionizing Radiation."

4.9.3 CFR 47, Telecommunications (10/1/91), Chapter 1, "Federal Communications Commission (FCC)," Subchapter A, Part 15, "Radio frequency Devices,"; and Part 18, "Industrial, Scientific, and Medical Equipment."

4.9.4 American Conference of Governmental Industrial Hygienists, “2005 TLVs and BEIs, Based on Documentation of the Threshold Limit Values for Chemical Substances and Physical Agents & Biological Exposure Indices,” 2005.

APPENDIX I

WARNING SIGNS

The warning symbol for identifying incident-electromagnetic energy consists of a black wave front radiating from a stylized point-source antenna on a white background. This symbol may be used as a part of safety signs that conform with danger, caution, and notice as specified in ANSI Z535.2.